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Evaluation of Body Size Parameters in Elite Angus Cattle

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EVALUATION OF BODY SIZE PARAMETERS
IN ELITE ANGUS CATTLE

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EVALUATION OF BODY SIZE PARAMETERS

IN ELITE ANGUS CATTLE

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ABSTRACT

The cattle shown at the prestigious All-American Angus Futurity were studied in order to evaluate the relationship between various body measurements. The measurements taken included wither height, hip height, body length, fat thickness, and weight. Also, these measurements were analyzed in order to determine if Angus cattle had gained in genetic frame size. Data were collected for the 805 animals shown in the years 1974 through 1978.

The cattle were grouped into classes based upon sex and age prior to any statistical procedures being performed. Means of classes were used in order to evaluate sex differences and bulls were found to be larger for all measurements. A comparison of the linear measurements and fat thickness of the old bulls with the corresponding measurements in the young bulls was utilized in a study of the maturity patterns present in the cattle. Also, coefficients of correlation were determined for all possible measurement combinations. The fat measurement was found to be less related to weight than either body length or body height. Wither height was the measurement most closely related to weight.

Wither height measurement was used in an analysis of variance of year effect on frame size. There were highly

significant differences in wither height that could be observed in the yearly means. The change in wither height was positive and consistant over the five years studied. The cattle did not increase in weight to the same degree that wither height changed and the changes in the fat measurements were inconsistent. However, the largest framed, leanest heifers occurred in 1978.

The coefficients of correlation determined in this study support the use of linear measurements and fat measurement in addition to, or as a substitute for, weight in making selection decisions. Also, the regression equations develcped help document the idea that it is possible to accurately predict weight through the use of skeletal measurements and fat thickness. The findings support the hypothesis that Angus cattle have become genetically larger framed over the past five years.

CHAPTER I

INTRODUCTION

The value of objective measures of growth in beef cattle has long been appreciated. Performance records, consisting mainly of weights and ages, are now available on a large percentage of the breeding stock being produced in the United States. However, with the current interest in beef carcass cutability accentuated by mandatory yield grading of beef carcasses and with the concern about economy of gains because of expensive feed grain costs, the use of weight alone as a measure of the breeding value of bulls and heifers has been questioned. The use of linear measurements and body composition data in order to more accurately describe beef cattle performance has become increasingly important in recent years.

When using linear measurements and body composition information in conjunction with traditional weights, questions concerning the relationship of these measurements arise. Because of the relative difficulty of obtaining linear measurements, insight into which measurements are most accurate in describing weight at any given age would be valuable. Also, any consistent association among linear measurements would be helpful in describing certain individuals or groups of individuals. The question of whether objective body measurements at a given age can be used to estimate maturity is a very significant one. If linear measurements can be used in connection with fat measurements to estimate maturity, then the accompanying weight figure would be much more meaningful. Data collected from 805 Angus cattle were analyzed in order to arrive at the relationship between various linear measurements, fat thickness and weights.

A further principle purpose of this study was to determine if Angus cattle have truly become larger framed over the time period being considered. This would seem to be a worthy objective in view of the fact that among progressive Angus breeders, increasing frame size has been of utmost concern in recent years. Brody (1945) suggests that wither height is considered an excellent measure of true genetic growth and, therefore, the analysis for change in frame size was conducted using the wither height data.

CHAPTER II

LITERATURE REVIEW

There have been many studies involving linear measurements and body composition in beef cattle; however, a large portion of these studies are concerned with predicting carcass merit from live animal measurements (Tallis et al., 1958; Gregory et al., 1962; Teren et al., 1959; Black et al., 1938). These studies are of limited value in discussion of breeding animal measurements; hence, useful information for the present study is restricted largely to that work concerned with body measurements and growth rate.

Birth measurements. Meat animal breeders have long been interested in the relationship between body proportions at birth and subsequent growth and development. A measurement system for birth characteristics that would reliably predict future growth would be invaluable in early sire and dam evaluation, particularly in cattle, considering the long generation interval. Flock et al. (1962) in measuring 473 Angus calves at birth found an average birth weight of 63.4 lbs., average height at withers of 23.9 inches and average length of body of 20.8 inches. For the linear measurements involved, there were year to year differences; however, these differences were not consistent, hence the researchers contributed much of the difference to inaccuracy in measurements. Bernard and Hidiroglou (1968) in evaluating similar data found differences between bulls and heifers with the bulls being both longer bodied and taller at the withers. They also reported age of dam as a consistent contributor to differences in linear measurements of calves. This would confirm the findings of Flock et al. (1962) that older dams have heavier calves that are generally larger throughout the preweaning period. Flock et al. (1962) found no linear measurement that was highly correlated with preweaning performance. The value of obtaining linear measurements in addition to weighing at birth would seem to be of little significance, and also the practice of selecting for larger birth weights would be questionable (Flock et al., 1962).

Preweaning measurements. Body measurements of calves at ages between birth and weaning are not common in the literature. This lack of information may be explained by the difficulty of obtaining measurements of young calves. Furthermore, Brown et al. (1973b) suggested that milk production of the dam may be confounded with genetic growth ability in young calves. Brown et al. (1973a, 1973b), however, attempted to determine the relationship between four month weight and subsequent growth in Hereford and Angus cattle. They found that weight at four months was more closely related to total preweaning gain than was any linear measurement. Also, the width at hips and loin and the height at withers were related to total preweaning gain, with the width measurements being more closely associated with early gaining ability than wither height (Brown et al., 1973b). In this same study post-weaning performance was evaluated and positive correlations were obtained for all dimensions measured at four months and post-weaning rate of gain in Hereford cattle. However, in Angus cattle, only height at withers and height at hips were positively related to post-weaning growth. These researchers concluded that Angus bulls that were wider at the hips and shoulders were perhaps early maturing and therefore showed slower gains on test. When feed consumption was measured in the post-weaning test, a high positive relationship was found between frame size measurements and total feed consumed in both breed groups; however, the amount of feed consumed per pound of gain was not consistent for the two breeds. In the Hereford breed there was a positive correlation between four month dimensions and feed conversion, however, the inverse was true for the Angus bulls on test. The correlation between the four month dimensions and feed conversion was negative with the possible explanation being that the Angus cattle were demonstrating earlier maturity (Brown et al., 1973b).

Brown et al. (1973b), in considering the relationship of four month measurements and final weight, found that in the Hereford breed, skeletal size measurements were more highly related to final weight than was four month weight.

In the Angus breed, skeletal size and weight at four months were about equal in their relationship to final weight. Considering all the cattle in the study, weight at four months and length of body at four months were the best predictors of final weight.

Weaning measurements. The relationship of body measurements at weaning to performance later in life has been studied extensively, possibly because of the availability to measure at weaning time, or more probably because of the desire to predict what animals should be treated as possible sires or dams for the following generation. However, even though weaning time is a very opportune time and is indeed a time of decision, Brown et al. (1973a) suggest that weaning age is a stage in the life of a calf that provides many sources of undesired variability. These researchers mention unpartitional dam influences, the stress of weaning, and the effect of puberty as possible sources of unaccountable variation. Because environmental factors influence weight to a much greater extent than sketetal dimensions, the use of frame measurements to evaluate growth would seem reasonable (Brody, 1945).

Most evaluations made of breeding prospects at weaning time involve only a weight measurement and an adjustment for exact age and possibly some environmental considerations. However, Brown and Shrode (1971) say "the body measurement and body composition traits appear to be of value as a means of obtaining accurate description of the true growth potential of beef calves." Brown et al. (1973b) studied the relationships of linear measurements at eight months with both preweaning growth and post-weaning growth in Hereford and Angus bulls. Weight at weaning was more highly correlated with preweaning rate of gain than any of the linear measurements. Height measurements were more closely related to preweaning performance than body length and height at the hips was the height measurement more closely related to preweaning growth.

In considering the relationship of eight month measurements and post-weaning gain on test, Brown et al. (1973b) found major differences between the Hereford and Angus breeds. In Herefords, it was concluded that the genes influencing eight month weight also had a strong positive influence on total gain on test, however, in the Angus breed, this was not true. Angus bulls that were large at weaning, often due to maternal effects, did not regularly perform better on test. In the Angus breed those genes causing wider animals at weaning resulted in poorer performance on test.

In considering total feed consumed, Brown et al. (1973b) found both weight at 8 months and height at the withers to be highly correlated with total feed consumed. They further concluded that body weight was as good as any linear measurement for predicting feed consumption. This would support the common feedlot practice of allocating a certain amount of feed for each hundred pounds of animal body weight.

The relationship of body measurements and feed conversion was not consistent over both the Hereford and Angus breeds (Brown et al., 1973b). Herefords that were structurally large at weaning converted feed more efficiently than those that were smaller. However, the inverse again was true for the Angus breed. Brown et al. (1973b) again alluded to the maturity pattern differences. Those heavier weaned Angus calves appeared to be farther advanced on their total growth curve than the smaller calves. The smaller calves on post-weaning test were able to convert feed better because they were still building muscle and bone and were not yet producing large amounts of fat. This maturity pattern explanation was supported by Brown and Shrode (1971) who state that "at a given age, the amount of fat deposition reflects differences in growth curves which are related to growth rate throughout the animals life." This fat deposition would at least partially explain the differences in feed conversion because of the relative inefficiency of fat production with respect to TDN utilization.

Considering fat deposition as a separate variable, Brown and Shrode (1971) found that fat thickness at weaning was positively related to total fat deposition. The tendency was for fatter animals at weaning to continue to be fatter throughout the post-weaning test period. Brown and Shrode (1971) concluded that fat measurement at any given point in life was an important consideration because of the desirability of lean meat and the cost of fat production. These factors, plus the generally recognized negative effect of excess fat on maternal ability, suggests that consideration of fat thickness is very important in selecting sires and dams.

Yearling measurements. The weight and measurement of a beef animal at about one year of age is very important for a number of reasons. It is at this point that the decision must be made as to whether an individual should be used as breeding stock or prepared for slaughter. Also the post-weaning performance can be evaluated relatively free of maternal effects. Another important reason for the value of yearling weights is that bulls are very often reaching a size that parallels the average slaughter size of steers going to market. Hence the length of time required for a bull to reach slaughter size measurements is helpful in determining a bull's utility. However, certain environmental conditions may have a masking effect upon measurements taken at one year of age. The most critical is that of post-weaning environment as related to energy intake. Also such factors as general health, parasites and weather conditions can effect yearling measurements. However, these environmental conditions should influence weight more than linear measurements which suggests that some linear measurements could be very useful (Brody, 1945).

Most of the literature concerned with yearling measurements discusses the relationship of pre-yearling measurements with yearling measurements. That body of literature has been discussed in the earlier portion of this review. Also, any discussion of the relationship of the various linear measurements to one another and to weight and age is related to the more general topic of maturity and maturity patterns. These combined topics will be discussed in full later in this review. There are several specific comparisons that can be cited involving measures at one year of age. Bernard and Hidiroglou (1968) found that at one year of age the coefficient of correlation between height at withers and body length was about .9. However, the correlation between height at withers and body weight was .54 and the correlation between body length and body weight was .58. Ternan (1959) further stated that the coefficient of correlation between height at withers and height at hooks was very high. This would account for the common practice of using only one height measurement to evaluate frame size. Brown and Shrode (1971) used one year of age as a time to observe differing growth patterns in the sexes. They found that differences for all measured traits between the sexes were larger at one year of age than at any earlier age. They accounted for this by the cumulative effect of true physilogical differences, differences in the effect of puberty, and certain environmental factors. Brown and Shrode (1971) were very concerned also about fat measurement and its relationship to other measurements at one year of age as well as throughout life. They imply that the greater the fat thickness relative to the linear measurements, the further advanced on the growth curve an individual is; hence the higher percentage of his final growth he has obtained. Using this theorem the conclusion can be drawn that animals who become fat at one year of age on only medium energy intake during the post-weaning period are nearing maturity for true skeletal growth.

Because yearling weight is the statistic most often available for bulls that are for sale to the public, an understanding of that weight is necessary if progressive decisions are to be made. Certainly knowing the composition of weight and a knowledge of the feeding regime in the post-weaning period would be helpful. Brown and Shrode (1971) were concerned with the influence of fat deposition as was Brody (1945) when he suggested that weight, width at both the chest and hips, and heart girth were measurements that would be increased in numerical value by fat thickness. Brody (1945) further concluded that height at the withers was the best index of the genetic size of an animal independent of energy intake. Black et al. (1938) concluded that the ratio of weight to height at withers gave the highest correlation with performance. Therefore, the conclusion can be drawn that height at the withers is a more reliable source of information regarding true genetic growth rate than is weight.

<u>Maturity and rate of maturity</u>. Any consideration

of measurements taken of beef animals after one year of age must deal directly with the issue of maturity. While no beef animal could be concluded to be physiologically mature at one year of age, the degree of maturity of individual animals could be different enough at this age to contribute significantly to the variation that might exist, particularly with respect to linear traits (Fitzhugh and Taylor, 1971).

Fitzhugh and Taylor (1971) defined mature size as the final size eventually reached for traits which seldom show negative growth. They suggested wither height as a very good determiner of mature size and body weight as a very poor one. Brody (1945) suggested that five years of age would be a reasonable average for virtual maturity in cattle; however, Calo et al. (1973) suggested that growth in the Holstein breed might occur up to an age of six years or longer.

Fitzhugh and Taylor (1971) in their discussion of rate of maturity, cite evidence to suggest that just as growth rate varies by stage of life, so does rate of maturity. An animal that matured at a rapid rate early in life might slow down after puberty only to accelerate in his maturity as he approached his final dimensions. However, they state that animals that have a rapid rate of maturity early in life generally reach mature size at a relatively young age. This concept is supported by Brown et al. (1973) in their work with Hereford and Angus cattle.

A negative relationship between rate of maturity and final mature size was reported by Fitzhugh and Taylor (1971). Animals that are more mature at any given age tend to be smaller at maturity and animals large at maturity tend to be relatively less mature at earlier ages (Fitzhugh and Taylor, 1971). This observation has implications in evaluating measurements of immature cattle in regard to their genetic ability for growth. Generally, selection for improvement in a specific measurement at a given age will be more effective in making improvement for that measurement than it will be for altering mature size (Fitzhugh and Taylor, 1971). This conclusion could lend credence to the general use of yearling size as an important selection criterion because the average yearling weights in the industry closely parallel the average slaughter size of steers and heifers.

By using various sources, it is possible to review the change in body proportions that occur from birth to maturity. Newborn cattle generally have relatively long legs and short shallow bodies (Brody, 1945). On the average, the wither height at birth is fifty percent of its mature measurement, while body weight and width of hips are only six percent and thirty percent, respectively (Brody, 1945). As an animal grows the buttocks and loin grow at a faster rate than the head or legs (Brody, 1945). Brown and Shrode (1971) suggest that as the animal grows the hip height gradually decreases relative to the wither height but even at maturity the hip height remains greater.

Ternan (1959), however, described changes in growth reflecting no relative changes in height measurements but a rather constant relationship with the animal being slightly taller at the hips. Also, as an animal matures fat deposition increases because of a decreased need for energy for frame and muscle growth (Brown and Shrode, 1971).

Linear measurements add much to the credibility of cattle performance records (Brown and Shrode, 1971). Brody (1945) concluded that weight and age alone cannot be used to effectively represent the genetic potential of an individual for growth, and that of all the linear measurements possible, wither height was the best measure of true genetic size. In order to properly evaluate any measure of size, a knowledge of body composition and of maturity and degree of maturity is necessary (Brown and Shrode, 1971; Taylor and Fitzhugh, 1971). The relative values of linear measurements, fat deposition and weight provide insight into the stage of maturity of an animal and allow the animal breeder a better opportunity to select genetically superior animals.

CHAPTER III

MATERIALS AND METHODS

The data for this study were collected from all the Angus cattle shown at the All-American Angus Futurity in the years 1974 through 1978. In each of the years studied, approximately 160 animals were shown to give a total of 805 individuals in the study. About 60% of the cattle were heifers to give a total of 482 heifers and 323 bulls.

The All-American Angus Futurity is a special prestigious show that attracts only the most progressive Angus breeders. The animals in this study represent the very elite members of the Angus breed and provide a unique opportunity to measure the progress being made by the best breeding programs in the breed. The Futurity was held the first week in August each year at the Kentucky Fair and Exposition Center in Louisville, Kentucky. All linear and fat measurements were taken on the Saturday immediately preceding the show on Monday and Tuesday of the following week. In the years 1974-1976 weights were taken on the same day as the other measurements. In 1977 and 1978 the animals were weighed immediately preceding their entering the show ring.

All linear measurements were taken by the same individuals in each of the five years being considered. The height measurements were taken with a device that consists of a calibrated bar and two crossmembers. The bar is held upright with the stationary crossmember placed on the ground and the moveable crossmember allowed to rest on the animal at the point of reference. The moveable crossmember has a level mounted on it. This level enables the operator to be confident that the upright bar is perpendicular to the ground and is providing the true height measurement. The device described here is identical to an instrument developed by the Wye Plantation at Queenstown, Maryland, for use in measuring their Angus cattle. The height at withers was taken at the third or most prominent thoracic vertebra. This vertebra is at the midpoint of the shoulder and represents the highest point of the shoulder. The height at the hips measurement was taken using the hook bones as the point of reference. A steel measuring tape was used in obtaining the length measurement. The length measurement represents the distance from the midpoint of the shoulder to the most prominent caudal vertebra. This is the longest possible measurement that can be taken of the animal body if one begins at the midpoint of the shoulder.

In the years 1974 and 1975, the fat measurement was obtained through the use of an ultrasonic scanning device. This device was affixed to a Polaroid camera that provided a photograph of a cross section of the animal immediately above and including the loin at the point midway between the twelfth and thirteenth ribs. The fat measurement was then taken directly from the photograph by measuring the fat depth at 3/4 the distance from the backbone to the lateral edge of the Longissimus dorsi. In the years 1976-1978, an ultrasonic device that provided a direct fat measurement was used. This device provided a measurement of the fat depth at the same point above the Longissimus dorsi between the twelfth and thirteenth ribs. Even though these two methods are somewhat different, the results are comparable and no significant variation should be expected.

For all major statistical procedures, the animals in this study were divided into three groups. Group I consisted of all heifers between 12 months and 20 months of age. This group totaled 388 head and was the largest of the groups studied. Group II was composed of bulls between 12 months and 20 months of age. These were the intermediate size bulls and this group contained 186 head. Group III was composed of bulls between the ages of 20 months and 30 months. This group of large bulls totaled 85 head and was the smallest of the groups considered. Those animals that were less than one year of age were not included in the primary statistical procedures because of the many possible sources of variation (Brown et al., 1973b, Brown et al., 1973a) and also because of the fact that there was wide variation in the ages of the young animals shown each year.

Coefficients of correlation were obtained using standard statistical procedure as outlined by Steel and Torrie (1960). Also, Steel and Torrie (1960) suggested the method by which the analysis of variance was conducted. F values were obtained and their significance tested at the 0.05 and the 0.01 levels. A stepwise multiple regression procedure as outlined by Draper and Smith (1966) was used. In this procedure, height at the withers, body length, and fat thickness were used as independent variables in an attempt to predict the dependent variable body weight. This stepwise procedure provided a method of determining which independent variable accounted for the greatest amount of variability in the dependent variable. The remaining variable that accounted for the greatest portion of the residual variability entered the equation next with this procedure continuing until all independent variables were fitted.

CHAPTER IV

RESULTS AND DISCUSSION

In order to describe each of the three groups being studied, the means and standard deviations for all measurements are presented in tables 1, 2, and 3. Each group includes a rather wide range of ages; therefore, means do not accurately describe animals of a particular age. However, the groups were taken from similar age ranges each year, thus the means are suitable for analysis of year differences.

A comparison of corresponding measurements between Table 1 and Table 2 indicates that there were large sex differences between animals of the same age. The bulls were larger for all measurements which is in agreement with the findings of Brown and Shrode (1971). This study supports the conjecture of Brown and Shrode (1971) that true physiological differences do exist between bulls and heifers and that this difference would be manifest in the linear measurements. Brown and Shrode (1971) suggested that post-weaning management differences contributed to the differences in linear measurements between bulls and heifers. It is logical to assume that bulls and heifers in this study

TABLE 1.--Means and standard deviations for all measurements in Group I (heifers from 12 to 20 months of age)

Year	Wither Height	Hip Height	Length	Fat Thickness	Weight
1974	46.27 ± 1.34		46.09 ± 2.01	.312 ± .112	891.52 ± 97.10
1975	46.58 ± 1.34		46.65 ± 1.72	.347 ± .110	
1976	47.02 ± 1.18		46.96 ± 1.55		923.43 ± 93.47
1977	47.18 ± 1.25		48.16 ± 1.60	.344 ± .103	
1978	47.81 ± 1.30	48.73 ± 1.87	47.9 ± 1.64	.284 ± .087	

TABLE 2.--Means and standard deviations for all measurements in Group II (bulls from 12 to 20 months of age)

Year	Wither Height	Hip Height	Length	Fat Thickness	Weight
1974	48.73 ± 1.48		48.21 ± 2.22	.217 ± .117	1166.15 ± 139.55
1975	49.72 ± 1.24		50.35 ± 1.69	.205 ± .074	1233.65 ± 119.88
1976	50.11 ± 1.53		50.99 ± 2.02	.298 ± .095	1284.21 ± 140.05
1977	50.13 ± 1.19		51.86 ± 1.90	.291 ± .095	1256.00 ± 134.85
1978	51.12 ± 1.60	52.09 ± 1.78	52.66 ± 2.03	.267 ± .106	1323.48 ± 129.82

TABLE 3.--Means and standard deviations for all measurements in Group III (bulls from 20 to 30 months of age)

Year	Wither Height	Hip Height	Length	Fat Thickness	Weight
1974	53.25 $\pm$ 1.54		53.46 $\pm$ 2.57	.416 $\pm$ .199	1691.58 $\pm$ 216.48
1975	53.95 $\pm$ 1.31		55.34 $\pm$ 1.40	.314 $\pm$ .115	1743.57 $\pm$ 148.73
1976	53.88 $\pm$ 1.25		56.41 $\pm$ 2.34	.461 $\pm$ .153	1797.37 $\pm$ 178.15
1977	54.47 $\pm$ .82		59.19 $\pm$ 1.18	.470 $\pm$ .175	1860.29 $\pm$ 106.87
1978	54.37 $\pm$ 1.06	55.16 $\pm$ 1.51	57.9 $\pm$ 1.63	.393 $\pm$ .145	1820.06 $\pm$ 163.57

were provided similar post-weaning environmental conditions.

Coefficients of correlation for all the measurements within each group are given in tables 4, 5, and 6. In each of the groups the coefficients of correlation between height at the withers and weight and between length and weight were about equal in value. However, contrary to the findings of Bernard and Hidiroglou (1968), the coefficient of correlation was slightly greater between height at the withers and weight than between length and weight in all groups with the difference being substantially greater in group II. The coefficient of correlation between fat and weight was very low in all groups which would indicate that the effort on the part of Angus breeders to reduce fat deposition in immature animals has met with some success. The coefficients of correlation between body length and wither height were .65, .69, and .73 for Groups I, II, and III. These values are somewhat lower than the .9 reported by Bernard and Hidiroglou (1968). This would suggest the possibility of having animals that were extreme in either height or length while being only moderate in the other parameter. The difficulty of obtaining accurate wither height and length measurements should also be considered in evaluating this coefficient of correlation. In all groups the relationship of both height and length measurements to fat was very low but positive. This would indicate that even though the larger framed animals were fatter than their smaller contemporaries, the difference in frame size was

TABLE 4.--Coefficients of correlation among body measurements in Group I

Measurement	(5)	(4)	(3)	(2)	(1)
1. Wither Height	.751	.183	.694	.877	1.00
*2. Hip Height		.187	.718	1.00	
3. Length	.753	.265	1.00		
**4. Fat Thickness	.569	1.00			
***5. Weight	1.00				

*Based on data from 1978

**Based on data from 1974, 1975, 1976, and 1977

***Based on data from 1974 and 1976

TABLE 5.--Coefficients of correlation among body measurements in Group II

	Measurement	(5)	(4)	(3)	(2)	(1)
1.	Wither Height	.881	.357	.733	.946	1.00
2.	Hip Height	.882	.575	.800	1.00	
3.	Length	.733	.274	1.000		
4.	Fat Thickness	.414	1.000			
5.	Weight	1.000				

TABLE 6.--Coefficients of correlation among body measurements in Group III

	Measurement	(5)	(4)	(3)	(2)	(1)
1.	Wither Height	.795	.201	.652	.871	1.000
2.	Hip Height	.801	.320	.600	1.000	
3.	Length	.742	.225	1.000		
4.	Fat Thickness	.420	1.000			
5.	Weight	1.000				

relatively much greater than the difference in fat thickness. Using the maturity concept as presented by Brown and Shrode (1971) it can be stated that this relationship between frame size and fat indicates that fat animals at a given age will be relatively smaller framed than lean animals and will be nearer maturity if energy intake is equal. Also, Fitzhugh and Taylor (1971) suggest that the fatter animals were maturing at a faster rate toward a smaller mature size.

These coefficients of correlation provide information that can be very useful in cattle breeding programs. Most importantly they provide assurance that it is possible to breed cattle that are larger framed and heavier at a given age while remaining acceptably lean. Breeders therefore should not feel that they must use a fat animal simply because he is the heaviest or fastest gaining animal available. They should apply selection pressure on the frame size measurements and in so doing they will be moving toward a larger framed, leaner animal. From the previous discussion it can be seen that selection for larger framed animals will result in delayed maturity and larger mature sizes (Fitzhugh and Taylor, 1971). Some breeders question the acceptability of these maturity changes, and indeed, at some point frame size may become large enough and maturity delayed long enough that selection emphasis will have to be placed elsewhere (Taylor and Fitzhugh, 1971). Also, these coefficients of correlation between the frame size measurements implicate wither height and hip height as the best predicators of body weight. This fact, along with Brody's (1945) view that wither height is the best measure of true genetic skeletal growth, suggests wither height is the one best frame measure for a breeder to use.

In the study of the relationship of cattle measurements, regression analysis can be very helpful. Since weight is the statistic most often used by buyers and sellers of cattle, multiple regression equations were fitted to predict weight using body length, wither height and fat as independent variables. Because of the reduced emphasis given weight in heifers and also because of the limited data, an equation was not developed for predicting weights of heifers. The equations developed for group II and group III are described in tables 7 and 8. In each of these two groups a high degree of the variability in weight can be accounted for by the three traits used as independent variables. The conclusion can be drawn that accurate measures of height, length and fat would make excellent measures by which to estimate weight. Linear measurement would be more accurate than weight in describing actual body size because they are much less subject to short-term environmental influences. Also, frame and body composition measurements could be more useful than weight for they measure both growth and composition of growth rather than just growth alone.

With the intent of determining if Angus cattle have become structurally larger, an analysis of variance of year

TABLE 7.--Multiple regression equations for predicting weight for Group II

		b Values for				
Model	Y Intercept	Wither Hgt.	Fat	Length	R	R Square
M_1	-2664.346	78.42			.881	.777
M_2	-2522.174	74.79	155.38		.887	.789
M_3	-2477.561	65.88	152.71	7.91	.893	.797

TABLE 8.--Mutliple regression equations for predicting weight for Group III

		b Values for				
Model	Y Intercept	Wither Hgt.	Fat	Length	R	R Square
M_1	-4118.266	109.34			.7955	.633
M_2	-3620.317	74.53		24.46	.840	.719
M_3	-3406.336	71.05	244.304	22.20	.878	.770

effects was performed using the wither height measurement. The analysis of variance for year effects on wither height by group is shown in tables 9, 10, and 11. In group I, which consisted of all heifers over one year of age, there were differences in the wither heights ($p < 0.01$). When studying the means a gradual increase can be observed from year to year with the largest single increase occurring in 1978. In group II, bulls from 12 months to 20 months of age, there were differences in wither height ($p < 0.01$). These bulls demonstrated the same gradual improvement found in the comparable age heifers. Again the greatest improvement occurred in the last year. This increase in wither height of bulls and heifers during the rapidly growing part of their life indicates that Angus breeders have indeed been successful in selecting sires and dams to produce larger framed offsprings. In group III, those bulls over the age of 20 months, there were differences in the wither height means ($p < .05$); however, the differences were not as consistent nor as large as those found in the younger animals. There was a large increase from 1974 to 1977; however, there was little difference between 1977 and 1978. The difference between the younger bulls and the older bulls in regard to rate and direction of wither height change can be partially explained by the fact that there were differences in ages of the oldest bulls shown each year. The number of bulls in group III each year was much smaller than the number in group II so trends were more difficult to

TABLE 9.--Analysis of variance for year effect on wither height in Group I

Source of Variation	d.f.	Mean Square	F Value
Years	4	24.1557	14.817**
Error	383	1.6303	
Total	387		

TABLE 10.--Analysis of variance for year effect on wither height in Group II

Source of Variation	d.f.	Mean Square	F Value
Years	4	25.8732	12.993**
Error	181	1.9913	
Total	184		

**Significant at ($p < .01$)

TABLE 11.--Analysis of variance for year effect on wither height in Group III

Source of Variation	d.f.	Mean Square	F Value
Years	4	4.2222	2.805*
Error	80	1.5054	
Total	84		

*Significant at ($p < .05$)

observe. However, a major reason for the inconsistency of increase of height measurement in the older bulls could be the varying stages of maturity present. This would be consistent with the maturity discussion as presented by Fitzhugh and Taylor (1971). Group II bulls were immature; however, there would be bulls in group III that were very near maturity. Those animals close to maturity would be growing much more slowly than those relatively immature individuals. This variability in stage of maturity and the wide age differences make this type of analysis questionable for cattle of this age.

The wither height measurement has been used to show that there were true frame size differences among years in this study. These differences have been consistently positive in nature. However, to answer the question of whether Angus cattle have truly become genetically bigger, other sources of change must be investigated. Would it be possible that this frame difference is simply a measure of an overall increase in the average weight of the animal and could this increase be environmentally caused rather than genetic in nature? In order to answer this fundamentally important question an analysis of variance of year effects was performed on the weight measurements. In group I there was no significant difference ($p > .05$) in the weights; however, weights of heifers were taken in only two years. Therefore, the lack of difference is not as meaningful as it might be. In group II there were differences ($p < .01$)

in the weights, however, the F value was much smaller than the corresponding F value for wither height (12.993 versus 7.121). In group III, the large bulls, there was no difference ($p > .05$) in the weights even though the numerical values for weight did show a gradual increase. The changes in weight values were proportionately much less than the changes in wither height values.

It is a reasonable assumption that if Angus cattle have gotten taller at the withers without having increased in weight proportionately, then fat deposition must have become less with time. In order to test this hypothesis an analysis of variance of the year effect upon fat measurement was performed. In group I there were differences ($p < .01$) in the fat measurements with the general trend being that the cattle had become leaner over time. An exception to this general trend toward leanness occurred in 1976 and 1977 when fat thickness actually increased (table 1). However, in 1978 fat depth was less than for any other year. A possible explanation for this rather inconsistent movement would be that in 1976 and 1977 breeders were attempting to gain size by increasing energy intake during the post-weaning period. This practice resulted in heavier animals, however, fat thickness increased a disproportionately large amount. Both the leanest and largest framed heifers occurred in 1978. In group II there were differences ($p < .01$) in fat measurement; however, again these differences were not consistent (table 2). The fattest animals in group II appeared in 1976 and 1977 with 1978 measurements being leaner than 1976 and 1977 but not as lean as 1974 and 1975. Again the argument that environment was not constant over all the years could be used to account for this inconsistency in fat thickness. In group III there were no significant differences ($p > .05$) in fat measurements over the years. However, in 1976 and 1977 the animals had the largest numerical value for fat and this parameter was slightly smaller in 1978. Fat depth in this group would seem to be subject to the same maturity influences as wither height.

In 1978 two height measurements were obtained. The height at the hips was measured in addition to height at the withers. In agreement with Ternan (1959) the coefficient of correlation between wither height and hip height was very high with a value of about .9. This high correlation resulted in hip height being related to the other measurements in much the same way as wither height (tables 4, 5, and 6). Also a linear equation was fitted in the same way as earlier discussed; however, in this case wither height was replaced by hip height. No improvement was seen in the predicting ability of the equation by using hip height.

Means were calculated for hip height and wither height for each class of animals. The classes correspond to the classes of animal as shown in the Futurity in 1978. These means grew closer together as the age of the animals increased. However, in agreement with Brown and Shrode (1971), the hip height remained slightly larger throughout the age range of the animals shown. Possibly if older animals could have been measured a more dramatic change could have been observed. Also, coefficients of correlation were calculated between wither height and hip height within the classes. The value of coefficients of correlation grew closer to one as the age of the animals increased. This too would support the concept that as maturity approaches, the wither height increases more rapidly than the hip height. Given this evidence, it would seem reasonable that an estimate of maturity can be made by observing the relationship between wither height and hip height.

From the information derived from this study concerning the changes that have occurred in Angus cattle over the five years, the conclusion can be drawn that Angus breeders are indeed producing larger framed cattle. Further, the assumption that this increase in frame size is primarily genetic in nature rather than environmental is supported by the observation that wither height has increased significantly and consistently while weight has not shown a corresponding increase. Also, the general trend toward leanness among the cattle studied would support the concept that the change in frame size in Angus cattle has a genetic basis.

CHAPTER V

SUMMARY

The purpose of this study was two-fold in nature. The first portion involved studying the relationship of wither height, hip height, body length, fat measurement and weight in Angus cattle. The second portion consisted of analysis to determine if frame size changes had occurred in Angus cattle over the years 1974 through 1978. Data were collected from all cattle shown at the All-American Angus Futurity in the years 1974 through 1978. In order to increase the accuracy and meaningfulness of the results, the animals were grouped into smaller classes within years based upon sex and age.

Height measurements and body length were found to be more highly related to weight than was fat thickness. Wither height was the skeletal measurement most closely related to weight. Sex differences were observed by comparing the measurements of heifers and bulls of comparable age. Bulls were found to be larger for all measurements.

There were highly significant differences in wither heights that could be observed in the yearly means. Angus cattle became gradually taller over the five years studied.

Angus cattle did not become heavier relative to wither height and there was inconsistency in the change of the fat thickness. The largest framed, leanest heifers were shown in 1978.

The various coefficients of correlation determined in this study support the use of linear measurements and fat measurements in addition to, or as a substitute for, weight in making selection decisions. Also, in an effort to predict weight using other body measurements regression equations were fitted using wither height, body length, and fat thickness as independent variables. These three variables accounted for 80% of the variability in weight. Finally, the hypothesis that Angus cattle have become genetically larger framed over the past five years is supported by the results of this study.

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